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QUESTIONS OF THE DAY, No. XXXII.

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MODERN ARMOR

FOR

NATIONAL DEFENCE

PRESENTING PRACTICAL INFORMATION ABOUT MATERIAL,
METHODS OF MANUFACTURE, COST, DEVELOPMENT, TESTS
AND APPLICATION, EFFECTS OF FIRE, RESISTANCE OF
PLATES, AND A COMPARISON OF THE RESULTS
THAT HAVE BEEN OBTAINED AT THE MOST
IMPORTANT COMPETITIVE TRIALS,
TOGETHER WITH STATISTICS

BY

WILLIAM H. JAQUES

LIEUTENANT U. S. NAVY

ILLUSTRATED

NEW YORK & LONDON

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The Knickerbocker Press

1886

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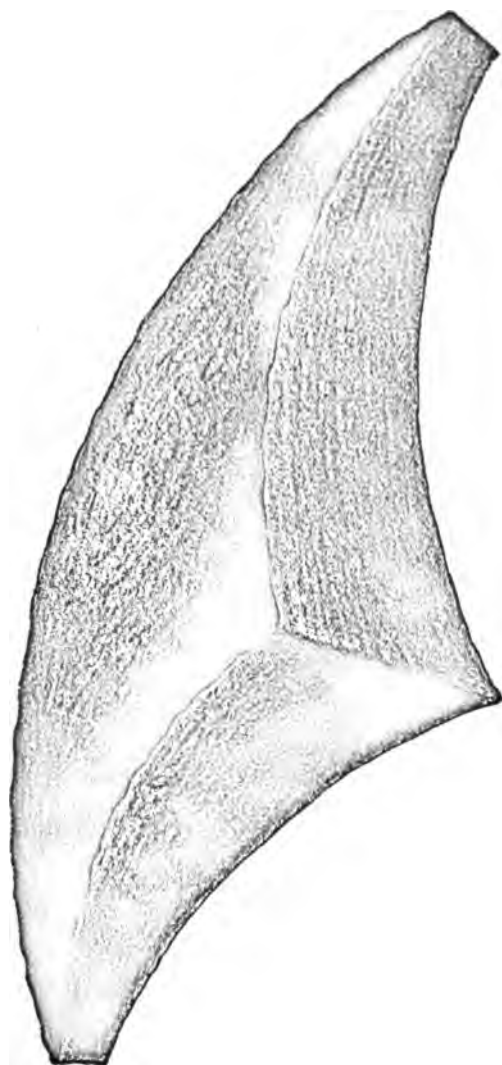
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TAPERED AND DOUBLE CURVED STEEL PLATE.

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MODERN ARMOR

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NATIONAL DEFENCE

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METHODS OF MANUFACTURE, COST, DEVELOPMENT, TESTS
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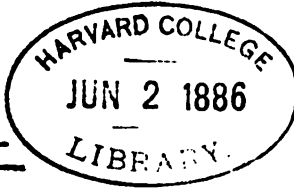
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NEW YORK & LONDON
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The Knickerbocker Press
1886

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OF
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THE AUTHOR

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W. H. JAKES
1886

MODERN ARMOR.

BY

LIEUTENANT W. H. JAQUES, U. S. NAVY.

IN considering the state and management of the public revenues, the subject involves the questions whether we shall extinguish the surplus by reducing the revenue, or whether we shall apply the surplus to payments on the public debt, or whether we shall seize the occasion to provide for our sea-coast defences, which have been long neglected. I am of the opinion that the latter is a paramount necessity, which ought to precede the reduction of the revenue, and ought, also, to precede an excessive rapidity in the payment of the public debt. * * * The defensive works would consist almost entirely of steel and iron.

S. J. TILDEN.

Steel and iron! To which of these should be confided the trust of defence? Economic as well as military reasons must govern the decision. Reading the various statements and reports upon the relative efficiency of different materials for protection against the fire of modern ordnance, it is most difficult to reach a conclusion as to the superiority of any one material over another for this purpose. Any thing from street rails to the best forged special steel is suggested as adaptable to a particular purpose, but

in the majority of instances no *definite* conclusions are presented.

It is not the intention of these few pages to follow the development of armor, or to present full descriptions of its manufacture and the experiments with it. These have been ably presented by Captain Orde Browne, R. A., in numerous papers; by Lieutenant E. W. Very, U. S. Navy, in his "Development of Armor for Naval Use," published by the Naval Institute, in 1883; by Lieutenant Emile Weyl, French Navy, in "Questions Maritimes," published by Berger-Levrault, Paris, in 1885; and fully treated in my "Establishment of Steel Gun Factories," published by the Naval Institute, in 1884. I am indebted to these authorities for assistance in the preparation of this paper, and I earnestly recommend them to all who desire to acquire exhaustive information on this special subject. In addition to the personal inspection of many targets, I have carefully searched the best authorities for the facts that would assist me to present the practical information relating to modern armor that appears at this time to be most needed.

To those who consider armor useless because the penetrating power of modern artillery is superior to the resistance of modern plates, I would call attention to the fact that circumstances attending target practice on the proving-grounds—the fire normal, guns on fixed platform, and the range only a few hundred feet—are very different from those in battle, where

the range is great, the armor fitted to the fort or ship is constructed to present the least amount of normal surface, and the attacking gun and moving ship are ever changing their positions. According to Noble, one of the ablest English artillerists, a thickness of armor equal to one half the diameter of the projectile will ensure almost certain impenetrability in the ever-varying conditions of a battle at sea.*

MODERN ARMOR.

DEFINITION.

THE term armor is at present applied to the metallic protection † of forts and ships which the increased power of modern artillery has rendered necessary.

* In a sea fight armor does not lose its power of resistance ; the gun, on the contrary, loses much of its power in an attack.—WEYL.

† The main object to be accomplished in the development of armor is to protect the vulnerable things behind it. It must be remembered that the ultimate object of naval armor is to attain the greatest amount of protective power with the least possible weight, and since there is a minimum limit of space to be defended which cannot be reduced, the reduction of weight must be accomplished by a reduction in thickness.—[Very.]

I wish to make it clear that it is so intolerable to have a hole made in a shield and to get a shell far through it so as to explode in the interior, that I look upon it as a certainty that armor should always be made hard enough to stop that.—[Browne.]

If a projectile succeeds in completely piercing the side of a vessel an immense water-course is opened ; if the breach is near the water-line very grave injuries are thereby caused, which, being of vital importance, are especially guarded against by the application of armor, and these injuries become still more disastrous if the breach be opened by a shell piercing and exploding inside. A single blow well directed might suffice to disable an iron-clad.—[Report of Italian Commission, 1876.]

KINDS.

There are four kinds—cast-iron, wrought iron, compound* (wrought iron and steel), and steel. Cast-iron and wrought iron are now only used for forts. Compound and steel may be used for either forts or ships. Captain Orde Browne classifies armor as *soft* and *hard*, "the former signifying armor which is perforated, and the latter armor which refuses to yield in this way and must be broken up."

MANUFACTURERS AND MODE OF MANUFACTURE.

The number of manufacturers of armor is exceedingly limited in consequence of the cost of plant, the skill and experience required, and the uncertainty of a market.

CAST-IRON ARMOR.

This is principally manufactured by Gruson of Buckau, near Magdeburg, Prussia. His method of manufacture is secret, but a chill mould is used which renders the outer surface of the plate very hard, while the inner surface remains soft. Very gives the following description of the manufacture of Gruson chilled cast-iron armor :

The first operation performed at the Gruson factory, in the construction of an armored fortification, is to build a full-sized plaster model of the fort, each block being separately moulded

* A few experimental compound steel plates have been mechanically manufactured, but the results of their trials have not been made public.

and put in place. From this plaster cast, the exact shapes of the different curvatures are obtained, and the second part of the operation, that of making the chill mould, is then proceeded with. This chill mould is itself made of cast-iron, which is run in an ordinary sand mould, the latter having been made from the plaster mould, and forms the base of the main block mould. Upon the chill mould a sand mould is built corresponding to the remaining end, side, and interior contour of the block. What may be termed the trade secret in the construction of this armor rests entirely in the choice of the pig, its treatment in the furnace, and the care in the casting. Herr Gruson claims, and apparently with reason, that his factory is the only one in the world that can make such immense chill castings (ranging from 20 to 50 tons each) successfully. It is certain that the Russians tried repeatedly and unsuccessfully to make these castings without surface-cracks; and when it is considered that it required years of practice to make perfect so small an object as a chilled 9-inch rifled shot, the skill and knowledge required for the operation can be appreciated. The pig metal being melted in the furnaces, is tapped off into a single large receiver, and from there is fed directly into the mould. When the latter is full, a surplus of molten iron is allowed to run around the upper part of the mould so as to retard the cooling of the unchilled portion. When the casting is cooled, the work of the construction of the block is practically finished, for nothing remains except the ordinary finishing foundry work. The ends of each block are slightly hollowed, and when the blocks are put in position finally, zinc solder is run into the cavity formed by the close-fitting adjacent ends of blocks, securing them together and thus avoiding all bolts or fastenings of any other description.

This armor is used for forts in Germany, Russia, Holland, Italy, Austria, and Belgium. It was at one time adopted for inland forts in France, but broke

up so easily under the effects of *steel* shot that it was condemned and is no longer used.

Every experiment with the Gruson cast-iron armor shows the immense influence the curved surface has upon its resisting power ; while its great weight and size, and the fact that the whole advantage of the chill is lost in the flat plates, unfit it for application to vessels. Again, it must be remembered that it never has been subjected to such severe tests as steel and compound armor have received, and although its cost per ton is less, the larger foundations necessary would make the final cost of the turret or casemate equal to if not greater than that constructed of steel.

The greatest thickness of cast-iron plates is 43 inches. Weight, from 50 to 80 tons. Price, from \$150 to \$200 per ton.

WROUGHT-IRON ARMOR.

At one time there were many manufacturers of wrought-iron armor in England, France, Germany, and Russia ; but since 1879 it has been practically abandoned for ships, as it has been found that both compound and forged-steel armor possess from 20 to 25 per cent. greater resisting power for the same thickness. Although wrought iron is still used in England for forts, steel possesses many advantages. It is somewhat more costly per pound ; but its power of resistance is so much greater than that of wrought iron that the plate-upon-plate system, that will have

[illegible]

mechanically joined.* Great efforts have been made to produce the latter variety successfully, but up to the present time no vessel or fort has been supplied with it. Therefore in using the term compound armor the present English systems will be meant.

Great confusion still exists in regard to the names of the compound armors. This has arisen from the fact that the managing directors—John Devonshire Ellis, of the firm of John Brown & Co., and George Wilson, of the firm of Charles Cammell & Co.—are the patentees. Hence the armor is sometimes named from the manufacturers, and as often called after the patentees. The Brown plates are made under the Ellis patents, and the Cammell plates under the Wilson patents.

With reference to the mode of manufacturing compound plates, the iron back is made by the ordinary method of manufacturing wrought-iron plates, and is common to the two establishments. The method at present employed by Brown is to lay the forged-steel-face plate over the wrought-iron plate, from which it is separated by a wedge-frame round three sides, and rows of steel blocks called distance pieces. Thus prepared, they are carried to the heating-furnace, where, after covering all exposed steel surfaces with gannister, they are raised to the proper temperature and transferred to a vertical iron pit, where a

* The compound plate then becomes virtually a steel one, differing solely in method of manufacture.—[Very.]

to be adopted to get the required thickness with the latter, the increased length and cost of bolts, and the largely increased cost of transportation and fitting tell heavily against wrought iron.*

Of the numerous plants capable of turning out wrought-iron plates, the principal manufacturers are :

Charles Cammell & Co., Sheffield, England.

John Brown & Co., Sheffield, England.

Marrell Brothers, Rive-de-Gier and Couzon, France.

Petin & Gaudet, Rive-de-Gier, France.

Terre Noire Works, Terre Noire, France.

The greatest thickness of wrought-iron plates of guaranteed quality is 12 inches. Weight, about 40 tons. Price, from \$220 to \$336 per ton. As 12 inches of wrought iron are easily perforated by a 6-inch high-power breech-loading rifle, more than one plate must be employed if the armor is to be at all efficient. The additional cost of fastening and sand-wiching these will increase the cost of wrought-iron protection to more than that of the steel plate of an equal power of resistance.

COMPOUND ARMOR.

This term is applied to armor which is composed of a hard steel face and a wrought-iron back joined together, or of a hard steel face and a soft steel back

* Foreign experts, as a rule, have always accepted the development of wrought-iron armor as a necessary evil, clearly foreseeing its limits.—[Very.]

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hydraulic ram holds all the parts securely and prevents the bulging of the face plate. Molten steel, either Bessemer or open hearth, is then poured into the space between the plates, and after sufficient time has been allowed for it to solidify, the whole is placed in a hydraulic press of 6,000 tons' capacity and the thickness reduced about three inches. The plate is then finished by reheating, passing through the rolls, bending, planing, and fitting it for the service required.

Cammell heats the wrought-iron plate to the required temperature, and rolls it into an iron mould that works on trunnions. The mould is then lifted by a crane to a vertical position and landed into a pit, where it receives the open-hearth or Bessemer steel which is to constitute the hard face. After solidifying, the plate is finished in the rolls.

Two thirds iron and one third steel are still accepted as the best proportions. Both methods give practically the same results under fire. Major Mackinley, R. A., writes, 1885 : " Ellis' plan has the advantage of a very good front surface, but the results attained by each are generally considered to be about the same, as far as present experience has shown."

Compound armor is manufactured under the Ellis patent by John Brown & Co., Sheffield, England, and under the Wilson patent at the following establishments : Charles Cammell & Co., Sheffield, England ; Aciérie de la Marine, St. Chamond, France ; Marrell

Frères, Couzon, France ; Chatillon et Commentry, Montluçon, France ; Direction du Dillengen Huttenwerke, Dilligen Saar Rhienprusse (where the manufacture has been carried on for two years) ; Kolpino, sixteen miles from St. Petersburg, Russia (where the first plates are now being manufactured, under an English director).

While the greatest thickness of compound plates yet made for a ship is 19 inches, with a weight of about 50 tons, the English barbette and turret ships now building will be side-armored with but 18 inches. Price, from \$425 to \$480 per ton, in an English port. The reported price (delivered in the United States, exclusive of duty) for the compound plates for the turrets and pilot-houses of the "Miantonomoh," furnished by Cammell and Brown, was £110 sterling (\$535) per gross ton for the plates, and £95 (\$462) additional per ton for the bolts.

STEEL ARMOR.

In the course of the development of armor, all the manufacturers of wrought iron and compound plates have at one time or another turned their attention to steel. Whitworth in England produced some excellent thin plates, but with this exception the sole successful producer of all steel armor has been the firm of Schneider & Co., Le Creusot, France.

Though they manufactured the wrought-iron armor of the French batteries in the Crimea, they

early became convinced that the true development of armor was in the direction of solid steel plates, whatever might be the thickness of armor required. They are now the only manufacturers of heavy steel armor and, besides possessing methods of composition, tempering, annealing and treatment generally, which no one has been able to equal, they have a valuable experience that enables them to rapidly increase the efficiency of their production.

According to Simpson :

The ingots for armor are cast nearly cubical in form, with a head on one surface for the adjustment of the porter bar. A large allowance is made for sinking head—from 25 to 33 per cent. The ingot with porter bar in place is heated in a furnace near the hammer, and is handled by curved jib cranes, which have considerable capacity of spring, which enables them to yield to the effect of the shock of the hammer. An ingot of 75 tons is usually heated about eight times before being reduced to its final shape, after which the edges are cut off with powerful tools, some working as slotting machines, but others as *circular saws*, which cut through 18 inches of steel. The plates are tempered in oil, but the exact requirements of the subsequent tests are not known.

The greatest thickness of steel plates yet made for a ship is 22 inches. Weight, about 45 tons. If required, Creusot has the capacity to make plates 32 inches thick, weighing 120 tons. The usual size of a 22-inch plate is about 12 feet long by 8 feet wide. Price about \$386 per ton in a French port.

At the request of the French Government Schnei-

der & Co. have submitted plans and estimates for steel turrets for land fortifications.

TESTS.

In making contracts for armor it is the custom in Europe to require its delivery in lots, and that one plate of each lot be subjected to a gun test, made at the expense of the government purchasing. This gun test varies in different countries, the tendency in England being to make it *less*, and in France and Italy, *more* severe from year to year.

In England the rule was established some years ago on the basis that compound plates might be about 20 per cent. thinner than wrought-iron plates of equal resistance, and conditions of test were adopted that would cause perforation of a wrought iron plate 20 per cent. thicker than the compound one. The range was established at 100 yards and three shots were fired, each projectile falling upon the point of an equilateral triangle, having sides 2 feet each, described upon the middle of the plate. The first shot must not produce any through cracks, and none of the shot must get through. At present, the English test only requires *one* shot of the same energy at the centre of the plate.

In France the present rule is that three shots shall be fired with an energy sufficient to penetrate a wrought-iron plate of the same thickness, together with an oak backing $2\frac{1}{2}$ times as thick. The projec-

tiles are fired at the extremities of a triangle $2\frac{1}{2}$ calibres apart, and none of them must go through the plate. A new rule is about to be adopted, as follows : The gun shall be just able to pierce the plate with a chilled-iron projectile. The plate must remain on the target until after the second shot. No projectile must go through the backing.

In Italy there have been a variety of tests, but the latest are as follows : For the "Italia," supplied in 1883 with English compound plates 19 inches thick, one shot capable of penetrating a wrought-iron plate of 25 per cent. greater thickness fired at the centre of the plate. The shot must not go through. For the "Lepanto," now being supplied by Schneider with steel plates 19 inches thick, three shots to be fired at the apexes of a triangle, each side of which is $2\frac{1}{2}$ calibres of the projectile in length. The energy of the first shot to be that which is theoretically necessary to pierce an iron plate of the same thickness. The projectiles in the last two fires to have energy sufficient to pierce an iron plate of 25 per cent. greater thickness.

In consequence of the enormous cost of these tests (over \$15,000), the Italian Government only test two plates out of the entire lot (1,800 tons) ; but they require that *every* plate shall have four test pieces cut from it, two from the outer and two from the inner corners, and the tensile strength, elongation, and elasticity of these specimens must average the same

as corresponding test pieces taken from the plates subjected to the gun test.

EFFECTS OF FIRE.

Of the behavior of different kinds of armor under fire, Orde Browne says :

Wrought iron yields locally ; it is punched or perforated, a clean hole being made in it. The rest of the target hardly suffers appreciably, except close to the point of impact. The plate yields at the back, opposite to the point of impact by tearing in a cross or star line, letting the point of the shot through the centre.

The *compound plate* yields mainly by cracking in radiating lines from the point of impact. In plates badly backed, the plate bends slightly back, and very rigid shot occasionally get their points through ; but when well backed, the entire plate must be broken in pieces and displaced before a shot gets past it in any sense. In addition to the radial cracks, concentric ones are apt to be developed.

Solid steel, as made by Schneider, though rather less hard than the steel face of the compound plates, is, as a mass, more rigid. It admits the points of the shot at first with rather less resistance, but it does not yield at the point of impact even when badly backed, and is, therefore, less dependent on backing than compound armor. I have never known of a concentric crack being made in steel armor, nor of the point of the shot getting through until the plate was stripped off.

Chilled iron made by Gruson is very rigid. The shot never, I believe, gets its point even a single inch* into the metal. The shield transmits the shock through its mass, and must be broken up bodily. Chilled iron is used in large masses, and is best suited to resist single blows, especially in an oblique direction. Under the direct blows of heavy shot of high

* Up to the present time, no projectile has ever penetrated a Gruson chilled-iron plate to a greater depth than 2.8 inches. (Griffen : "Our Sea-Coast Defence.")

tenacity chilled iron breaks up. Cracks radiating from the point of impact are formed, and the whole shield breaks across.

Omitting, therefore, further consideration of wrought and chilled iron, because of their want of sufficient power of resistance, let us notice the remarkable difference in the appearance of the steel and compound armor when under fire.

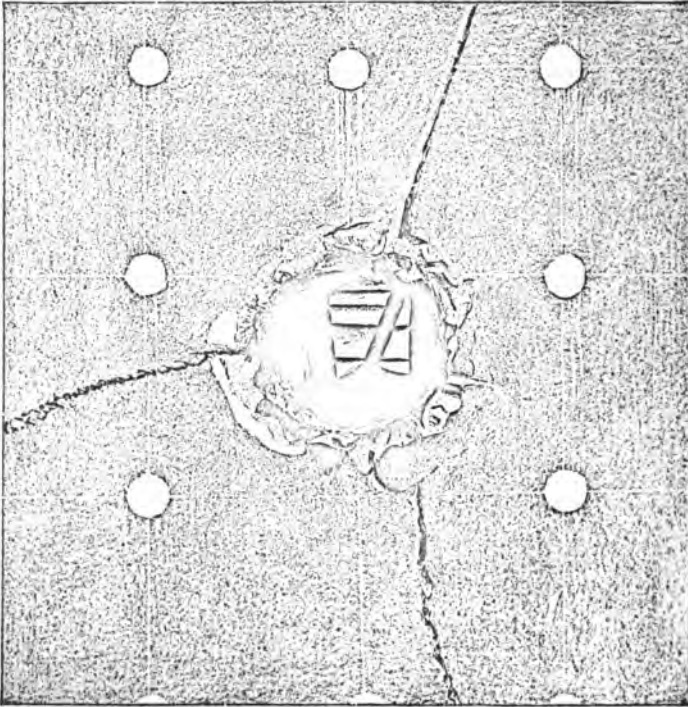


PLATE I.

When a thick steel plate is completely perforated, plate 1, the steel rarely shows a hole larger than the

diameter of the projectile, which acts like a punch ; from this hole cracks radiate.

In the compound plate, plate 2, circular cracks appear in addition to the radiating ones, and a circular piece,



PLATE 2.

considerably larger than the diameter of the shot is driven from the face of the plate through the back, forcing the plate open laterally and increasing the opening rapidly in diameter as the rear surface is approached.

The face of the plate in either case is dished or bent in considerably, unless the backing is absolutely solid; when the backing is not solid, the compound plate suffers far more severely than the steel, a matter of very serious importance in its application to the side of a ship.

COMPARISON OF STEEL AND COMPOUND ARMOR.

The steel face of compound armor contains about 0.7 per cent. of carbon, and its object is to deform or break up the projectile on impact, while the wrought-iron back holds the plate together and keeps the steel up to its work; the iron back is not expected to be of much value in keeping out the shot after it has penetrated the steel face. Major Mackinlay, R. A., thinks that compound armor has an advantage because its face is so hard, but considers that the union of the two materials, steel and wrought iron, probably leads to complication and uncertainty in results.

Schneider steel armor contains about 0.4 per cent. of carbon and is very carefully tempered. The outer surface of the plate is slightly harder than the inner surface and the object to be obtained is not only to destroy the shot on impact but to present as great and nearly uniform a resistance as possible throughout the entire thickness of the plate, so that it may hold together till the shot is broken.

Compound armor, therefore, shows to better

advantage, so far as a surface work is concerned, when the projectiles are poor than when they are good. This fact should not be forgotten, for great efforts are being made in Europe to develop projectiles. Whitworth, of Manchester, England, and Holtzer, of Unieux, France, produce the best at present; those of the latter are made of chrome steel.

In manufacturing compound plates, the principal difficulties to be encountered are in joining the iron and steel, and the difficulty is aggravated in joining steel and steel. Trials under fire develop a separation of the two metals, especially if the fire is oblique,* and a shot entering the back of a compound plate will penetrate the entire plate with very much greater facility than if striking the face; a fact which might be of importance in ships exposed to vertical or mortar fire. However good the iron for the back of the plate may be, it is rendered poorer by the reheating necessary to join it to the steel face, and the subsequent rolling has a tearing rather than a welding effect, because the two materials receive the work of the rolls in different degrees. This probably accounts for the fact that there is no compound plate in existence where the weld is perfect.

Curved plates, especially tapered and double curved (see Frontispiece), for which there is a con-

* In all naval conflicts the great majority of hits will be oblique, for in addition to the permanent obliquity given to the armor in construction, there is the constant alteration in position between the vessels engaged.—Very.

tinually increasing demand, are particularly difficult and expensive in compound manufacture. If bent after the plate is completed, the joint is liable to be broken, and if the steel face is cast on after the plate is bent, it is difficult to get the right thickness (which is very important), and the steel cannot be worked sufficiently afterwards.

In the Schneider plates these difficulties do not obtain, as each plate is a single ingot of homogeneous metal, worked down under a hammer to the necessary thickness and curvature, the great power of the hammer (100 tons) making very few reheats necessary, which is of very great importance to the quality of the metal. Up to this time no double-curved plates have ever been subjected to target practice, and trials of this sort will prove very instructive.

One of the most important features in connection with armor, is the manner in which it is fastened ; for the artillerist not only strives to perforate the plate, but to strain, loosen, dislocate, and shake off the armor and break the fastenings.* The bolt, therefore, not only has to hold the plate on the side of the fort or ship, but to resist vibration and prevent buckling. The best practice is to insert the screw-bolts into the rear of the plate without coming to

* From the earliest period of experiments trouble had been experienced with fastenings. The French were the first to modify the evil, and their first attempt at modification was such a success that their new pattern armor-bolt was retained practically unaltered until comparatively lately. By the introduction of the Schneider bolt this part of the armor seems to have well-nigh reached perfection.—Very.

the face, and in order to assist the plate in holding together till the shot is broken, and also that the shattered fragments may not fall, as many bolts as possible are desirable, provided they do not weaken the plate by penetrating too near the outer surface. Compound armor is at a disadvantage here over steel, as the back of the plate being laminated from rolling and not homogeneous, the bolt must be inserted further to obtain sufficient hold. The number of bolts in a compound plate is therefore less than in a steel one, though the bolts are of larger diameter. Creusot bolts are used by the French Government entirely for both compound and steel armor.

Regarding the efficiency of compound armor as manufactured on the Ellis and Wilson systems, John Brown & Co. state that "*they* are convinced that steel armor does not possess any advantage over the compound, as, although they could readily make both, they still adhere to the compound, and no other is used by the British Government."

On the other hand, it must be remembered that in all the latest competitive armor-plate experiments, the all-steel (Schneider) plate has been the victor * ; and although the British Admiralty were opposed to the verdict of the Italian Experimental Committee on the Spezia trials, they have presented no practical reasons to discredit it, nor does it appear that

* Report of Senate Select Committee on Ordnance and War Ships, 1886.

they have accepted the recommendations recently made to them to acquire a certain number of Schneider steel plates, if possible, and to have some competitive trials of their own. The Admiralty, I believe, have requested Mr. Schneider to furnish a few plates for the test of projectiles, but it is scarcely to be expected that Creusot will be willing to send its material for the investigation and information of the English manufacturers, unless the English Government will make a contract for the armor for one or more ships.

The following opinion of Admiral Simpson, U. S. Navy, who was President of the Gun Foundry Board, and President of the Naval Advisory Board, and who has given a long life to the study of ordnance questions ; and that of an English artilleryman, who has recently inspected the productions of the different manufacturers, and the results of the most important experiments, are pertinent and instructive :

My own judgment favors the steel plate. I think it more in the course of advanced ideas, and I am content with the results it has achieved in experiments ; and the more experience we have in the manufacture, the more will we approach perfection in results.

I am aware that at Terre Noire, in France, it is claimed that a good steel armor plate can be cast which needs no forging, and I am under the impression that the same idea obtains at one of our own large steel establishments, but I have no confidence in such material, and I think that the first shot from a modern

gun would dispel the illusion of those who entertain the idea. I accept as a fact that for the manufacture of steel armor plates there is required a heavy forging plant, and if we possess such facilities for forging our ingots for cannon, we have secured apparatus that will be equally serviceable for treating armor plates.*

The cost of a complete plant for the manufacture of compound armor would probably be as great as that for the manufacture of all steel armor, including a 100-ton hammer, but if the Whitworth hydraulic press be substituted for the large hammer, there will be much economy in the adoption of steel armor. †—Simpson.

The feeling among French officers is very general in favor of steel armor. The compound plates manufactured in France are equal to those made in Sheffield. Comparing the test plates at Gâvre, the steel plates were superior to the French compound; and the targets used for the last Spezia experiments show that the steel plate was much *superior* to the English.—English Artillerist.

DEVELOPMENT OF ARMOR.

For a very interesting history of the development of armor, I take pleasure in again calling your attention to the publications mentioned in the early part of this paper.

Early in the history of wrought-iron armor, it was found that a solid plate was some 33 per cent. stronger than a laminated one of the same thickness composed of one-inch plates; but when solid armor reached a thickness of 12 inches, the limit of guar-

* Extract from paper read before Washington branch of Naval Institute, December 4, 1885.

† Extract from Circular-Letter, Navy Department, July 8, 1884.

anteed regularity of manufacture was reached, and experiments were made with several thicknesses of heavy plates. The results obtained were better than where the plates were thin, but a practical difficulty was encountered in the enormous cost of fitting the plates accurately to each other (which is very essential), and the utter impossibility of doing so when the plates were curved. Resort was therefore had to the sandwich system (interposing layers of wood between heavy plates). This was found fairly satisfactory for forts, but not for ships, where weight and space are such prominent factors. The experiments at Spezia in 1876 having proved that hammered steel Creusot armor was better than wrought iron, either solid or sandwiched, the latter has been gradually given up for ship armor, and must soon give way to steel for forts.

Cast-steel armor (unworked) was tried by several firms, but it always broke up under fire, and was quickly abandoned.

Compound armor had been more or less experimented with for many years, but owing to the difficulty of securing uniformity in its manufacture, and the fact that wrought iron was still ahead of the development of artillery, we hear little of it until after 1876, when the success of French steel over iron caused the manufacture of compound armor to be rapidly developed in England, where the Government has made large use of it.

In reply to the claims that the Gâvre (French) trials of 1880, the Ochta (Russian) experiments of 1882, and the Amager (Danish) tests of 1884, proved the superiority of compound armor, an excellent answer is found in the following statement of Admiral Simpson * :

In 1880, a Cammell and Schneider plate were tested at Gâvre by the French Government, with a view to providing armor of the most perfect type for new armored vessels. The decision was in favor of the compound plate, but the report laid great stress on the possibilities of the development of steel, and in order to aid the Creusot works, a contract was made with Mr. Schneider for side armor for one of the ships.

When the selected armor plates were subsequently tested for reception, the steel plate proved to be superior to the compound plate.

In 1882, the Russian Government carried on a competitive trial between the Cammell and Schneider plates, at Ochta, near St. Petersburg. The result was decidedly in favor of the compound plate, but it was evident that the steel plate was not a fair sample of the manufacture, as its brittleness was apparent in its breaking up into several pieces.

In November, 1882, very famous trials were carried on at Spezia by the Italian Government, in which the 100-ton gun was used against the plates. The contesting firms were Brown, Cammell, and Schneider. Each submitted a test plate of 10 feet 10 inches in length by 8 feet 7 inches wide by 18.9 inches thick. These plates were fired at with a projectile weighing 2,000 pounds, a charge of powder of 328 pounds, and a striking energy per inch of shot of 372 foot-tons. At the second round the Brown plate was split into six pieces, all of which except one were thrown from the target.

* Extract from Circular-Letter, Navy Department, July 8, 1884.

At the second round the Cammell plate was smashed and knocked completely off the target.

At the third round a portion of the centre of the Schneider plate was broken out, and the upper right quarter was displaced.

In this competition the steel plate had the decided advantage, having withstood the effect of the second round without having its capacity of protection destroyed.

Competitive trials have lately been made by the Danish Government on the island of Amager, a suburb of Copenhagen, where a firing ground is established. The competitors on this occasion were four in number, Schneider, Brown, Cammell, and Marrel Frères, the latter submitting a compound plate manufactured under the Wilson patent, as in the case of the Cammell plate. The plates approximated to 9 inches in thickness, and were 4 feet 11 inches long by 6 feet 6 inches in width. The plates were bolted to a 9-inch oak backing, with skin plating and strengthening plates, and stiffened by angle irons, and braced in rear by heavy oak balks.

The guns used were a 15 cent. Krupp and a 10-inch Armstrong muzzle loader, using, respectively, a charge of 43 pounds, with a projectile of 112 pounds, and a charge of 69 pounds, with a projectile of 402 pounds. One shot was fired at each plate from the 15 cent. gun, the result being much the same in all cases so far as the shot was concerned, as it broke up, leaving the head sticking in the plates. The targets were all more or less cracked by this gun, the order of merit being: No. 1, Brown; No. 2, Cammell; No. 3, Schneider; No. 4, Marrel.

The first rounds from the 10-inch gun broke off the left half of the Schneider plate, and passed clear through the other plates, the order of merit being: No. 1, Brown; No. 2, Cammell; No. 3, Marrel; No. 4, Schneider. The failure of the Schneider plate was evidently due to brittleness.

Reviewing the competitive trials cited above, we may safely

conclude that the want of consistency in the results of the trials is not due to any want of uniformity in the compound armor. This manufacture has reached a high point of perfection, and the plates are produced with certainty as to their characteristics.

Such imperfections as they exhibit are due to the system of manufacture, not to the manipulation of separate plates, all of which exhibit a very uniform resistance to shot.

This has not been shown to be the case with all steel plates. The cases cited above show some instances in which the steel was superior and then again inferior to the compound armor, showing a want of uniformity in the results of the manufacture. The failures are always due to brittleness, but when this element is successfully suppressed the comparison is in favor of the steel plate. It would seem from this that the actual superiority of material rests with the steel, but that the problem of uniformity in manufacture is yet to be solved.

The question is a difficult one. The hardness of the steel is needed for the surface, but if this characteristic be continued through the whole mass, brittleness will ensue ; the effort must be made to combine a hard surface with a softer material behind it, but this must be achieved in one homogeneous mass. The development of this work is steadily progressing at Le Creusot, and the action of the French Government in ordering steel armor for four new ships indicates its confidence in the latest results.

Harder faces have been made without increasing the vulnerable cracking, and Whitworth has repeated his successes, combining tenacity with surface-hardness.

The following comparisons of the tests of the plates manufactured by Schneider in 1883 for the "Furieux" and those for the "Amiral Baudin" in

1884 will show the great progress that has been achieved at Creusot, the result of the additional experience and the improvements in details that have insured uniformity and precision.

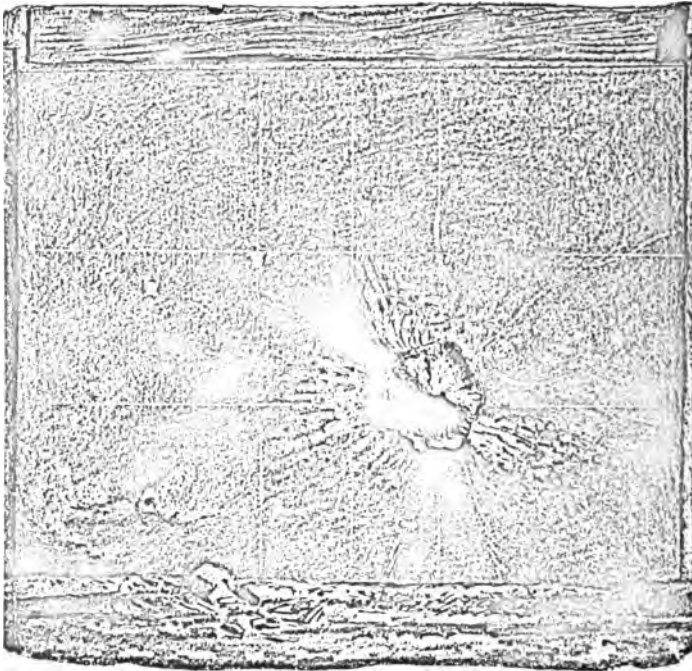


PLATE 3.—FIRST SHOT.

TESTS OF ARMOR PLATES FOR THE "FURIEUX."

The plate tested July 13, 1883, at the French proving-ground at Gâvre was manufactured at Le Creusot in the usual manner, and was a tapered plate for the starboard side of the belt. It was 9

feet 10 inches long, 7 feet 7 inches wide, from 16 to 18 inches thick, and weighed 23 tons 9 cwt. It was secured by 20 bolts, according to the Schneider system, to a wooden target of the form required by the

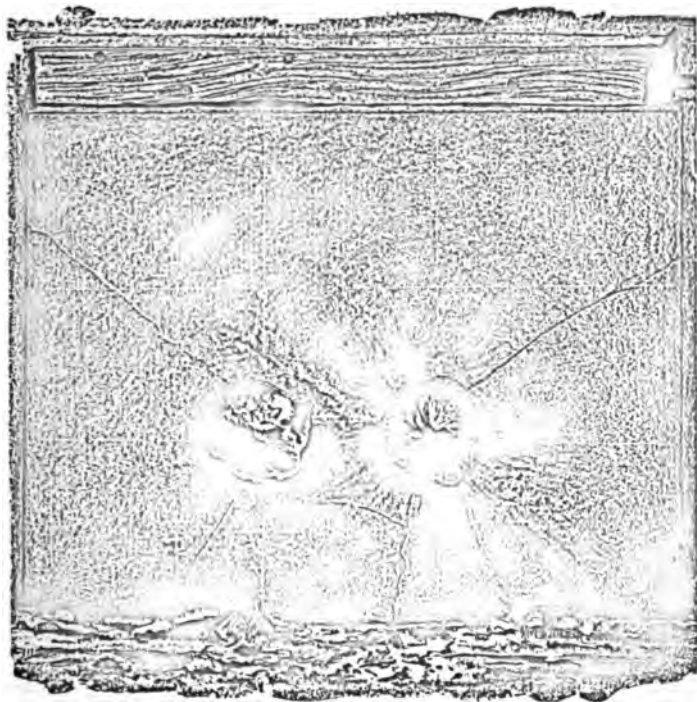


PLATE 4.—SECOND SHOT.

Gâvre Committee. Three shots were fired from a 32-centimètre (12.6-inch), model 1870, navy breech-loading rifle at the apexes of an equilateral triangle, whose base was horizontal and 31.5 inches long.

The projectiles were chilled shot, weighing 761 pounds. The first and second shots, plates 3 and 4 struck the plates at points 16.7 inches thick with a velocity of 1,416 feet per second. The third shot, plate 5, struck the plate at a point 17.3

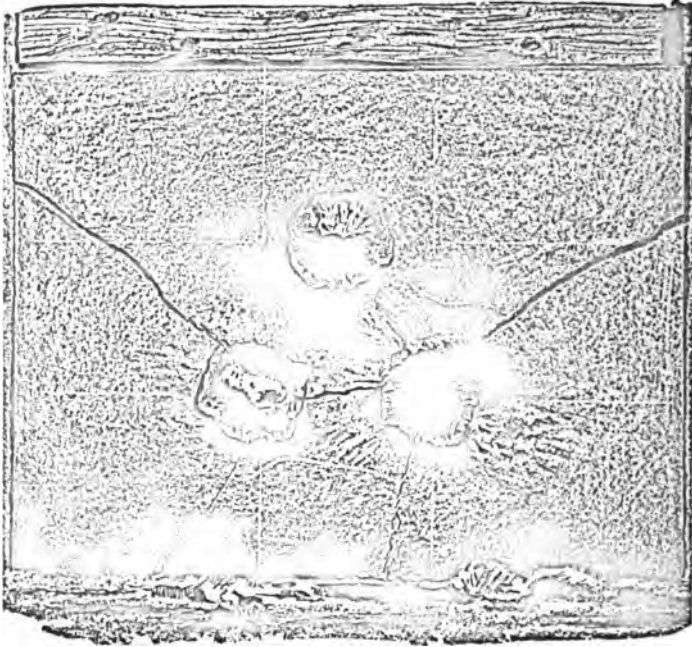


PLATE 5.—THIRD SHOT.

inches thick with a velocity of 1,452 feet per second. The projectiles were broken up, all the bolts remained intact, no portion of the plate fell from the backing, and the tests, as proposed, were more than met.

TEST OF ARMOR PLATES FOR THE "AMIRAL BAUDIN."

The plate tested March 7, 1884, was tried at the same place, with the same gun and under the same calculated conditions. It was manufactured at Le Creusot in the usual manner, and was a tapered

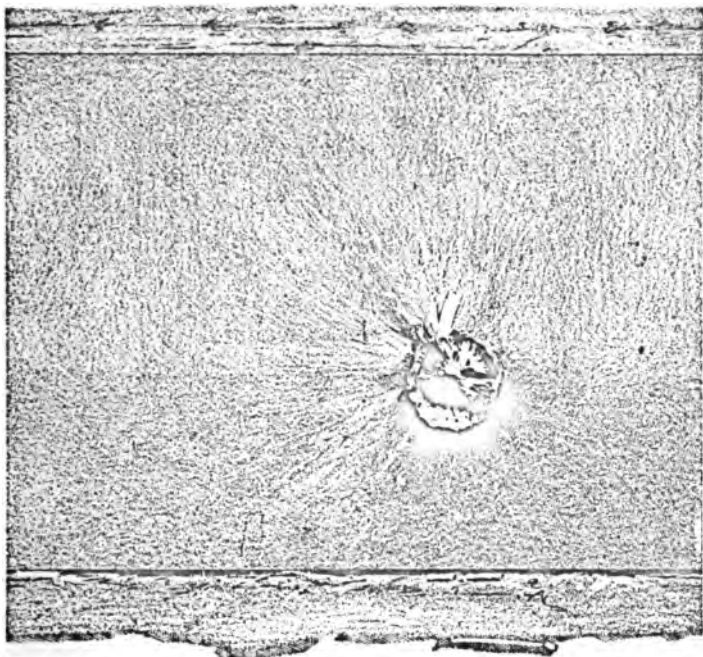


PLATE 6.

plate for the starboard side of the belt. It was 12 feet 9 inches long, 8 feet 2 inches wide, from 18 to 20 inches thick, and weighed 35 tons 9 cwt. The first and second shots, plates 6 and 7, struck the plate at points 18.5 inches thick with a velocity of

1,518 feet per second. The third shot, plate 8, struck the plate at a point 19.8 inches thick with a velocity of 1,593 feet per second. This plate was superior to the "Furieux" plate, as a comparison of the cuts will readily discover, and is an example of the

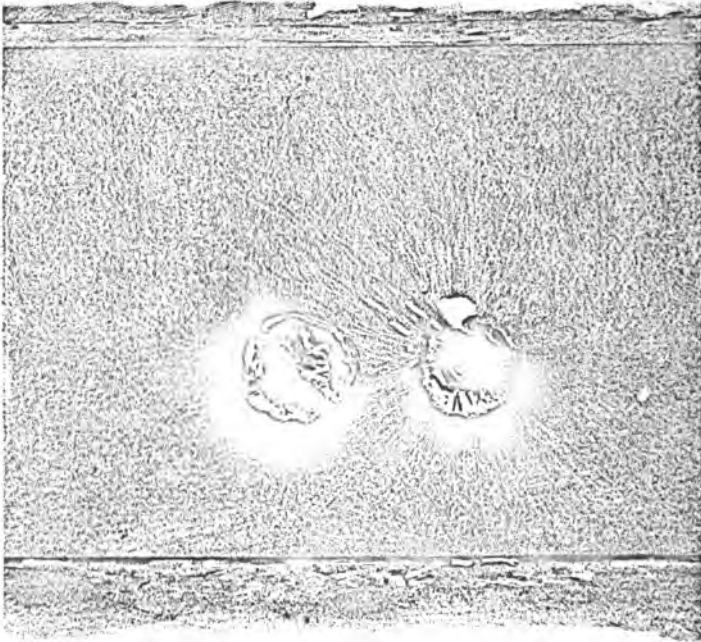


PLATE 7.

great progress that is going on at Creusot in the manufacture of solid steel armor. The slight damage done this latter plate demonstrates the wonderful power of resistance, tenacity, homogeneity, and uniformity that characterize the latest productions of the Creusot works.

In October and November, 1884, the latest public competitive trials of plates were made at Spezia, Italy, the object being to determine the most suitable armor for the line-of-battle ship "Lepanto." Plates 19 inches thick, weighing about 29 tons, were fur-

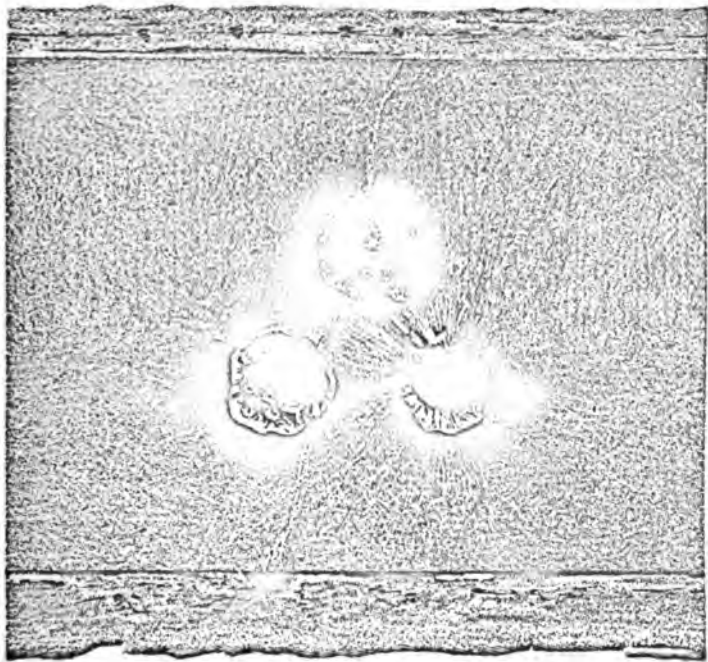


PLATE 8.

nished by Cammell, Brown, and Schneider. They were 10 feet long, 8 feet 6 inches wide, and were secured to the targets by 18 Schneider bolts. The targets were in front of a butt, and represented, as nearly as possible, the strength of the side of the ship.

The programme laid down required that each plate should be pierced by the 100-ton gun, whose projectile weighed 1,840 pounds, and which was known to possess more than sufficient energy for the purpose. After this shot, which was intended to distress the plate as much as possible with the most powerful gun in existence, each plate was to receive, without being pierced, four shots from a 10-inch gun, whose projectile weighed 470 pounds, in order to learn their endurance under the fire of a gun more nearly equal to the resistance of the plate.

The Schneider plate alone was able to endure this extraordinary test, the other plates going to pieces after the second shot from the 10-inch gun.

Plate 9 shows the effect of the fire of the 100-ton gun upon the Schneider plate (steel). The hole was uniform in its diameter, and very little larger than the diameter of the projectile.

Plate 10 exhibits the effect upon the Brown plate (compound), which was divided into four pieces. A portion of the steel face, nearly 5 feet in diameter, was torn off, and the perforation was 8 inches larger than the diameter of the projectile. One of the radial cracks was 10 inches wide.

Plate 11 shows the effect upon the Cammell plate (compound). It was also greatly damaged, one of its radial cracks being 10 inches wide. The hole through the plate was 10 inches larger than the

diameter of the projectile, and the six pieces into which it was transformed hung by the bolts.

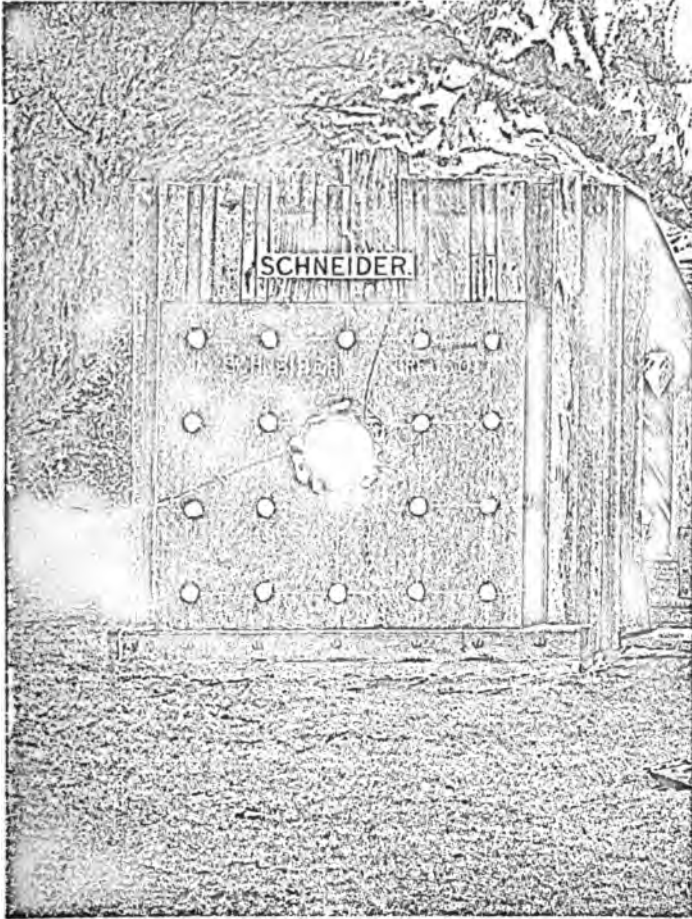


PLATE 9.

The Schneider target was the only one having its

braces and frames intact, and the only one that would have kept the ten-inch projectiles out of a

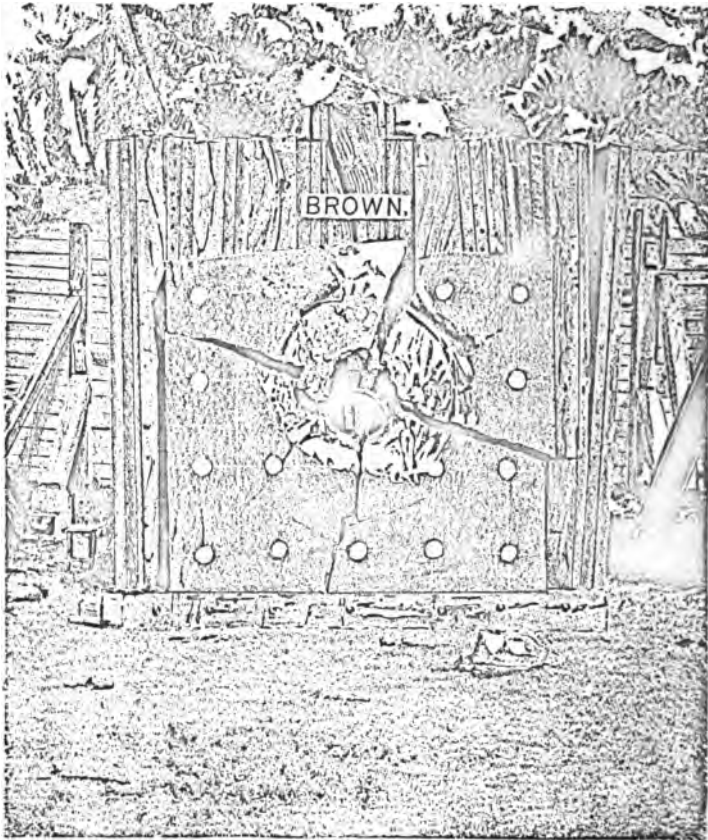


PLATE 10.

ship or fort. All of the projectiles used were of Krupp forged steel, hollow and tempered. A remarkable and most valuable feature of the trial was

that after receiving the shot from the 100-ton gun, the Schneider plate was so hot that for several hours it could not be touched within two feet of the hole

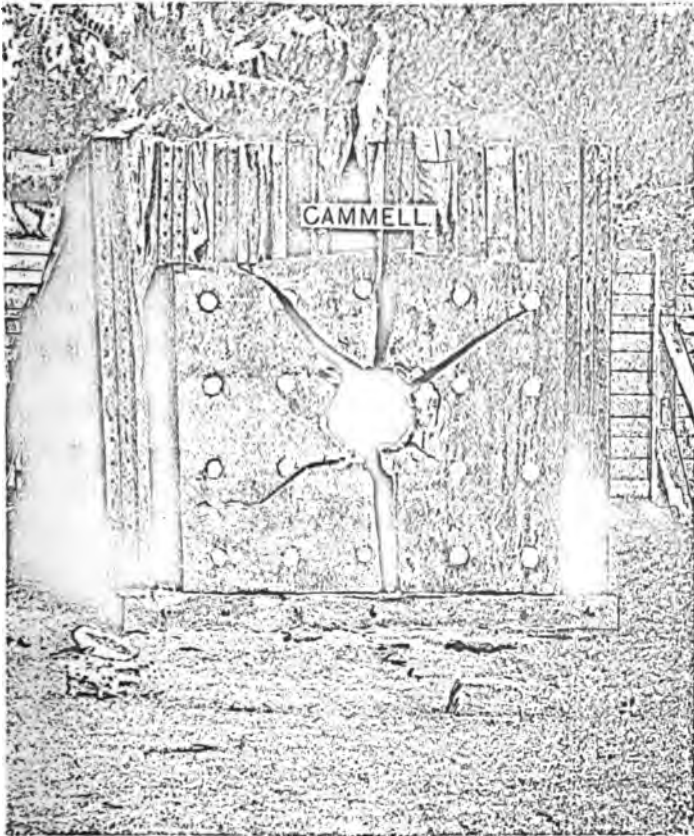


PLATE 11.

made by the shot, while in the compound plates the traces of heat were scarcely perceptible.

The importance that Lieutenant Weyl has given

this phenomenon should be most carefully considered, for it proves incontestably that the Schneider plate not only absorbed much of the force of the shot in breaking it up, but had received an immense quantity of heat, with which the projectile had parted in entering the plate. This is of vital concern, for if the heat thus generated by impact on the *steel* plate will cause the explosion of the shell-charge prematurely, before reaching the interior of the ship, the efficiency of the plate is greatly increased, and Weyl has rendered a most excellent service in discovering another valuable property of the solid steel plate.

The contract for the "Lepanto's" armor was given to Schneider & Co.

In estimating the efficiency of armor it must be remembered that the acceptance tests are in many cases less severe than the competitive ones, and that the backing and armor fastenings* have such an immense influence upon the results that great care should be taken to look to those competitive trials which have been conducted with the strictest equality of conditions. The scientific exactness with which the Italian experiments have been made entitle the results obtained at Spezia to be accepted as of the highest technical value. This cannot be said of the Danish experiments at Amager in 1884; the lottery of drawing the lucky position where the plate could

* The resisting power of the armor, as determined by the qualities of the metal plates, the disposition of the backing, and the distribution and strength of the fastenings.—Very.

be properly attached to the backing, completely destroyed the comparative value of the trials. Further, the plates were only of medium thickness. As a result, however, a contract was awarded an English manufacturer ; repeated reception tests, under this contract, in 1885, I understand, were unsatisfactory.

In Italy the results have been so decisive, and the Schneider steel plate has shown itself so far superior to the compound plates of the best makers, that the Italian Government has definitely committed itself to the exclusive use of Schneider steel by establishing works at Terni, near Rome, for its manufacture and development.

In regard to future development, I am not alone in the belief that the progress is limited to steel. Whether the best steel plate will be compounded mechanically—and there are those who believe they have devised the means,—or whether the Schneider hard front and soft back will reach the highest development by the means he now employs, the future must decide ; but the great cost of compound armor, and of sandwiching and accurately fitting wrought iron, added to their inferior resisting power and greater weight and space occupied, clearly demonstrate that for economic as well as military reasons *steel* is the best material for the armor of ships and fortifications.

STATISTICS.

Outside of England compound armor is used on 11* French, 2 Russian, 2 Brazilian, 2 Chinese, 1 Italian, 1 Danish, and 1 United States ("Miantonomoh") vessels. On the Continent, however, opinion is more divided than in England, and Schneider & Co. have furnished plates for 7† French, 1 Danish, 1 Swedish, 1 Spanish, and 4 Italian vessels; in all, including test plates, more than 20,000 tons.‡ The contracts for the armor of the French ironclads "Neptune" (10,581 tons), "Brennus" (9,780 tons), and "Charles Martel" (9,780 tons) have not yet been made.

The thickest side armor afloat to-day is that on the English line-of-battle ship "Inflexible," but it is of wrought-iron and sandwiched. It consists of a 12-inch plate, then 12 inches of teak, then another 12-inch plate, then 6 inches of teak strengthened by angle-iron girders, and lastly an inner skin of two 1-inch iron plates.

The thickest solid side armor afloat is that of the

* Six of these gun-boats.

† Two of these gun-boats.

‡ In comparing the amount of steel and compound armor furnished the French navy, it must not be forgotten that there are three firms in France manufacturing the latter, and that Creusot alone has furnished nearly as much as these other firms together.

two Italian line-of-battle ships "Duilio" and "Dandolo," which consists of 22-inch solid plates of Schneider steel. It has greater power of resistance than the armor of the "Inflexible."

The thickest solid armor that has passed the reception tests and is about to be floated is 22-inch Schneider steel for the two French line-of-battle ships "Amiral Baudin" and "Formidable." It is superior to that of the "Duilio" and "Dandolo," the steel being harder and tougher.

There are 198 armor-clad vessels in the world available for offensive operations against the United States, and 42 more are building, making a total of 240. Of these, 194 are plated with wrought iron, 19 with all compound armor, 12 with compound and wrought iron, 10 with all steel, 4 with steel and wrought iron, and 1 with steel and compound armor. Only 8 of the 42 now building have all wrought-iron armor, 6 of these being in Russia. Only 6 of the 240 vessels are under 2,000 tons' displacement; 209 of the 240 are over 3,000 tons'.

England owns 70 armor-clads, of which 13 are building.

France	"	50	"	"	12	"
Russia	"	24	"	"	6	"
Italy	"	19	"	"	5	"
Turkey	"	15	"			
Germany	"	14	"			
Austria	"	13	"	"	3	"
Denmark	"	7	"	"	1	is building.
Holland	"	7	"			

Spain owns 6 armor-clads, of which 1 is building.

Brazil	"	6	"	"	1	"
Japan	"	3	"			
Chili	"	3	"			
China	"	3	"			

Besides these vessels there are in Europe a large number of gun-boats, monitors, and other vessels for coast defence, and an immense number of un-armored cruisers.

The United States has ready for service but 6 monitors of 2,100, and 8 of 1,875 tons' displacement. These monitors are twenty years old, their guns are obsolete, their armor thin, and their power of offence or defence is insignificant. Besides these there are 4 monitors of over 3,800 tons each, and 1 (" Puritan ") of over 6,000 tons, in various stages of construction. The " Miantonomoh," at the New York Navy Yard, has hull and engines complete, and is being supplied with armor and guns. The " Puritan," " Amphitrite," and " Terror " are at private ship-yards ; they have the hull and engines practically complete, and are ready for their armor and guns. The " Monadnock," at San Francisco, has the hull complete, but requires engines, armor, and guns. These 4 monitors will require together about 3,000 tons of armor.

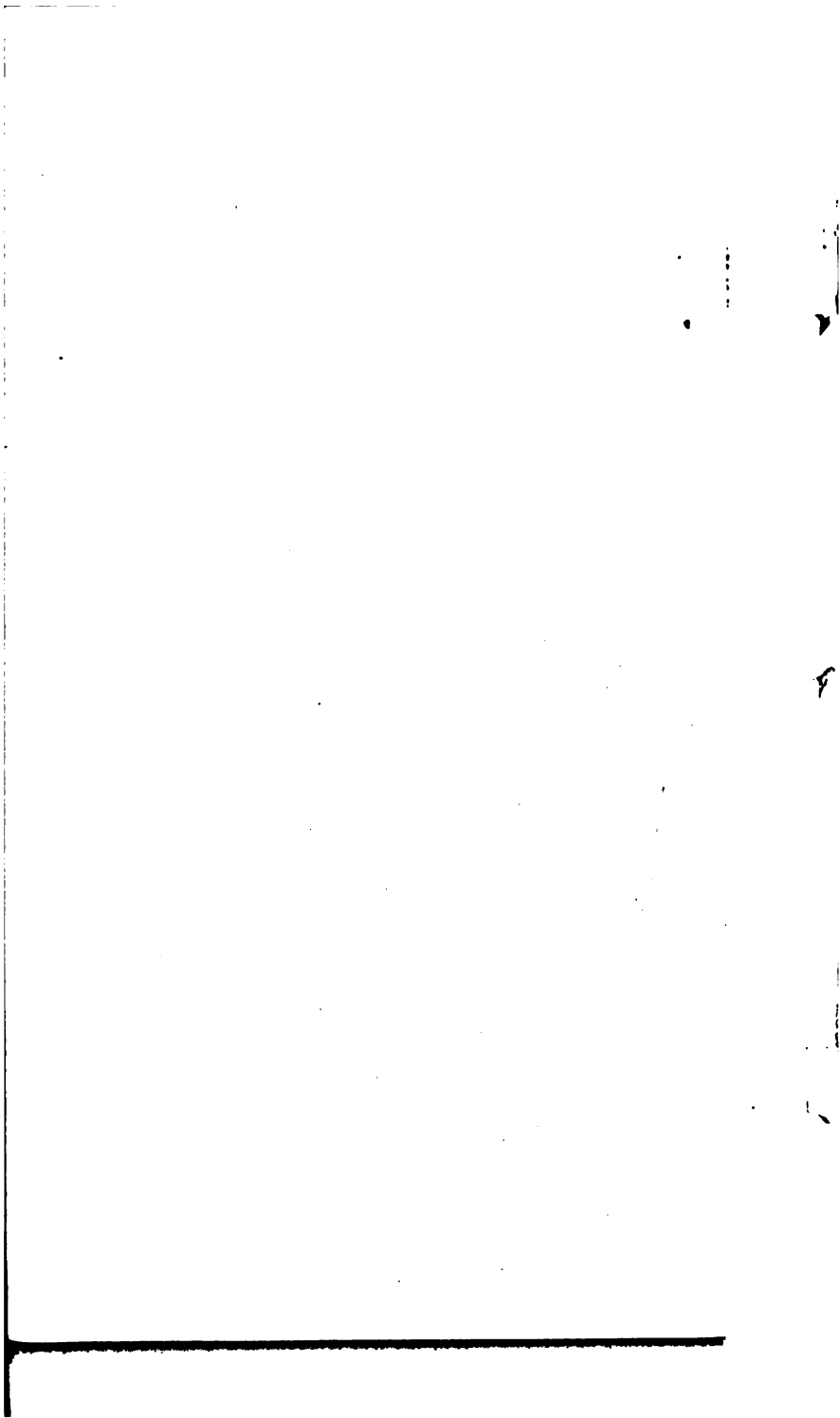
The 5 large monitors, if armed with 10-inch high-power steel breech-loading rifles, will make good fighting ships, and will be efficient for coast defence and for service in the West Indies or at the Isthmus

of Panama ; and if armored with *steel* plates instead of iron (for which they were designed), they will have a very much superior power of resistance with the same displacement.

The coast-defence fortifications of the United States are considered by all authorities to be about worthless ; we have no torpedo-boats nor automatic torpedoes ; and submarine mines and electrically controlled torpedoes can be easily taken up unless protected by guns and automatic torpedoes ; yet, from the estimates of Lieutenant Griffen,* U. S. Army, there is now exposed to the fire of an enemy on our coast, in eleven cities, nearly five thousand millions of dollars of destructible property.

* "Our Sea-Coast Defences," 1885. G. P. Putnam's Sons.





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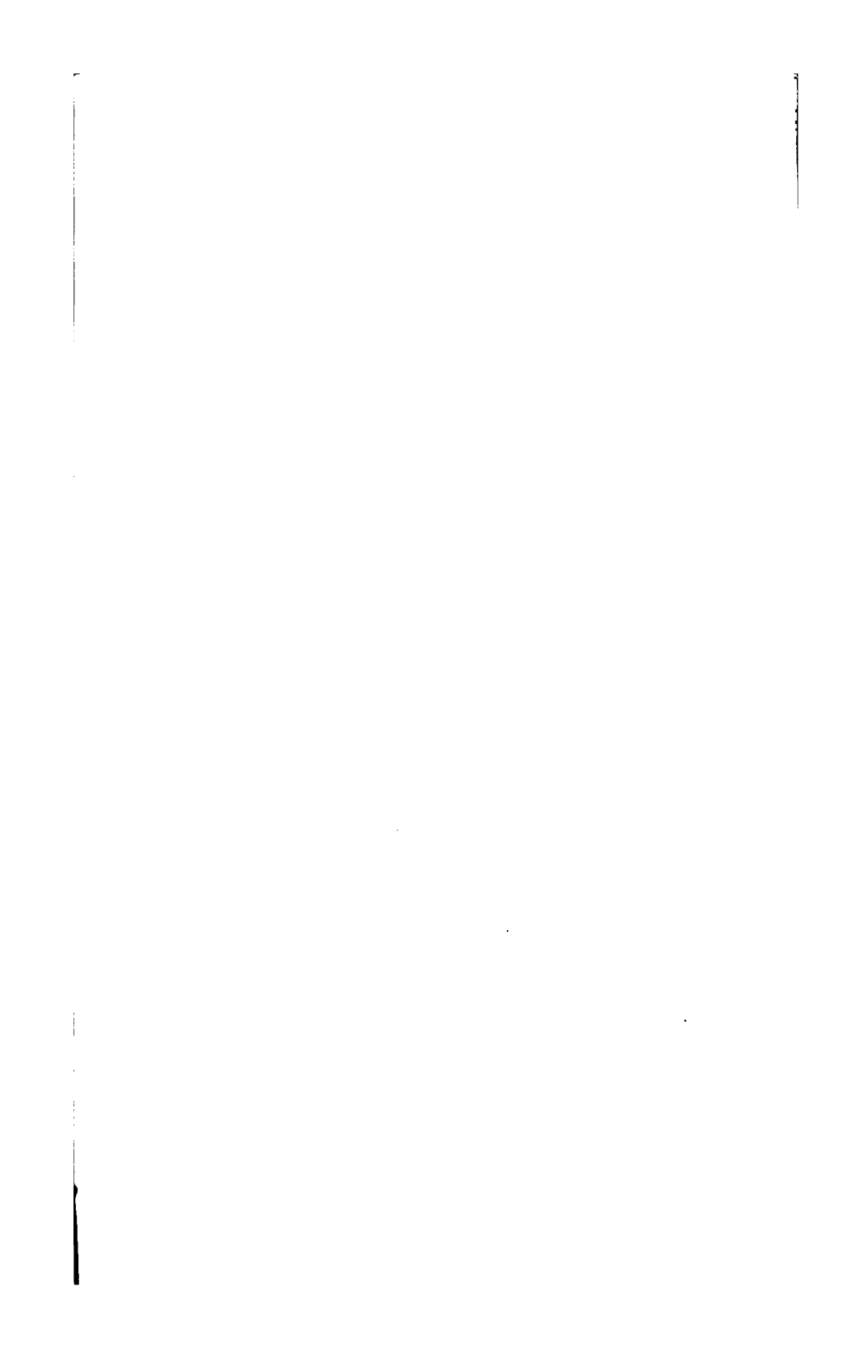
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